Dynamics of an entangled state under random magnetic fields

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Entanglement is an interesting aspect of quantum mechanics useful in quantum communication. The quantum communication protocols like quantum teleportation and superdense coding enable the sender and the receiver sharing maximally entangled pair of qubits to communicate information [1]. The property of entanglement, however, cannot survive indefinitely owing to disturbances. It is therefore necessary to understand the behavior of entangled states in the presence of disturbances. Among various objects that behave as qubits, we are interested in the spin-1/2 states of a particle and the random magnetic field that can cause disturbances. The dynamics of a single spin-1/2 particle in its pure state were already obtained in the presence of a random magnetic field due to which the pure state evolves into a random pure state [2]. The random magnetic field is modeled as Gaussian white noise process and the dynamics are derived using stochastic calculus. The relaxation times are obtained in the context of nuclear magnetic resonance. This idea is extended to the case of a pair of maximally entangled spin-1/2 particles that are spatially separated. The spins are subjected to random magnetic fields at their respective locations due to various sources which are in general different. We consider the most general case in which the components of the random fields are correlated [3]. This is inclusive of two special cases in which the random fields are same and independent. The dynamics are derived in terms of the joint density matrix assuming that initially the qubits are maximally entangled. This helps to understand how the entangled state behaves asymptotically and how long the entanglement survives when the constituent spins are subjected to disturbances. The timescale obtained from the dynamics is helpful to assess the possibility of implementation of the quantum communication protocols taking into consideration of the survival time of the entanglement. For instance, the pair of spins in the presence of independent random magnetic fields become totally disentangled asymptotically and the timescale associated with it, called the disentanglement time, helps to analyze how entanglement can be used effectively while implementing the protocols within the disentanglement time.

References

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